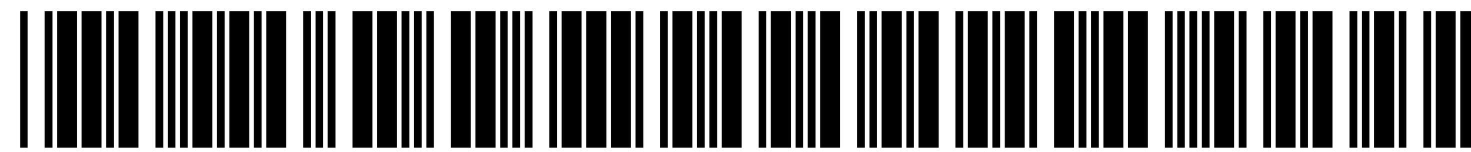
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Yang et al.

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(54) **METHOD FOR MAKING MULTI-CRYSTALLINE FILM OF SOLAR CELL**

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(51) **Int. Cl.**
H01L 21/20 (2006.01)

(52) **U.S. Cl.** **438/487**

(58) **Field of Classification Search** .... None
See application file for complete search history.

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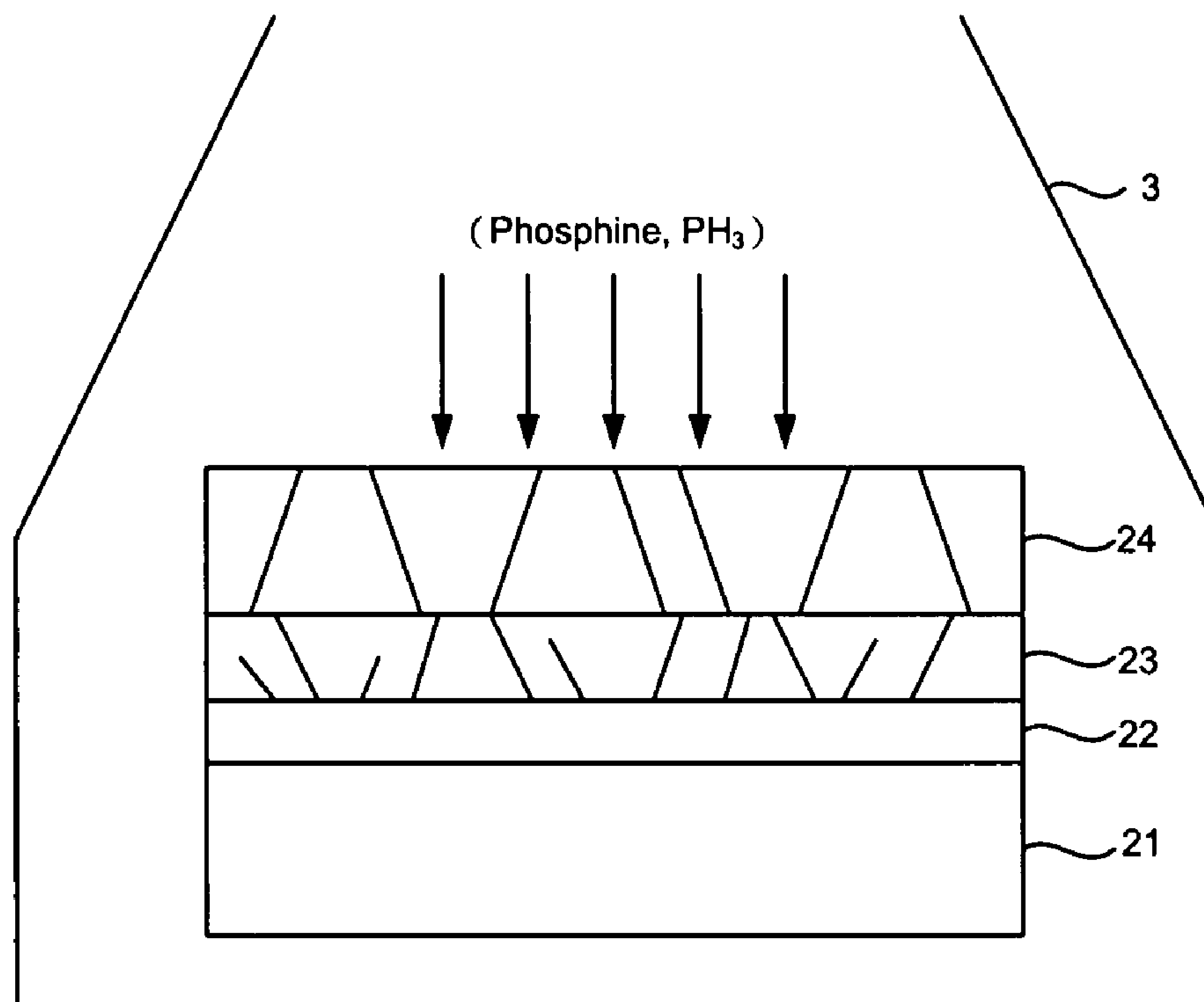
(57) **ABSTRACT**

A method is disclosed to make a multi-crystalline silicon film of a solar cell. The method includes the step of providing a ceramic substrate, the step of providing a titanium-based film on the ceramic substrate, the step of providing a p^+-type back surface field layer on the titanium-based film, the step of providing a p^--type light-soaking layer on the p^+-type back surface field layer and the step of conducting n^+-type diffusive deposition of phosphine on the p^--type light-soaking layer based on atmospheric pressure chemical vapor deposition, thus forming an n^+-type emitter on the p^--type light-soaking layer.

10 Claims, 9 Drawing Sheets



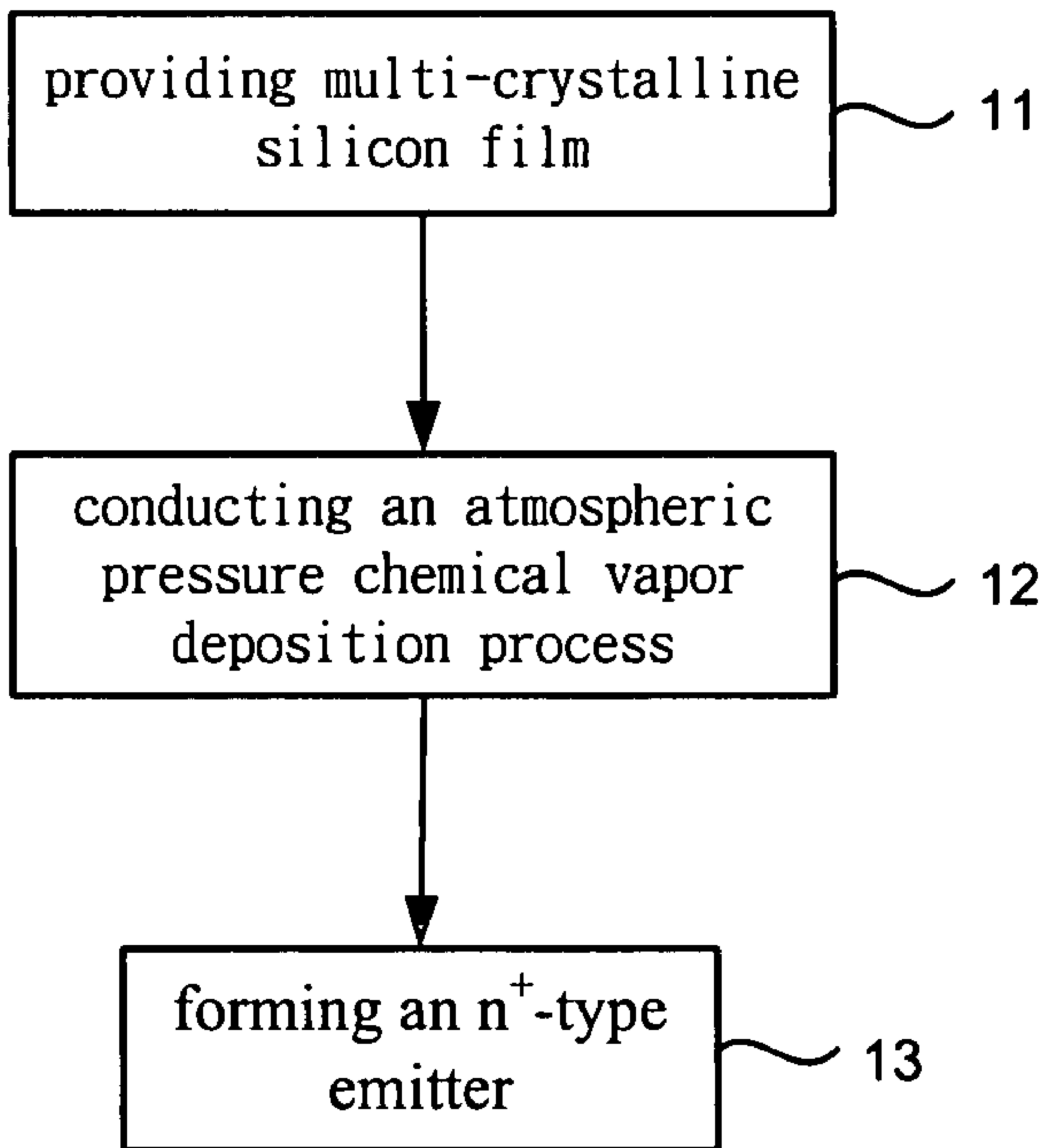


Fig. 1

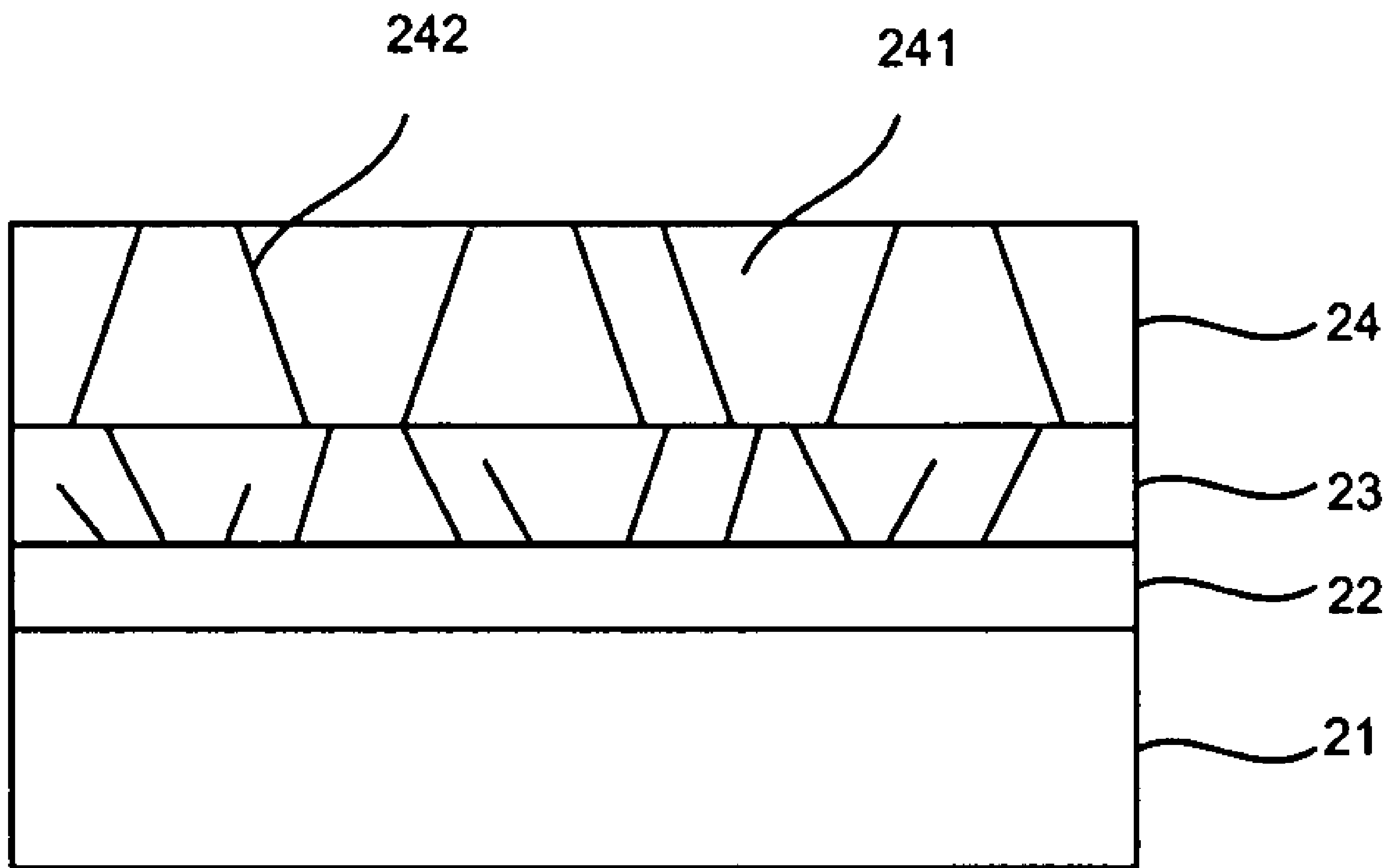


Fig. 2

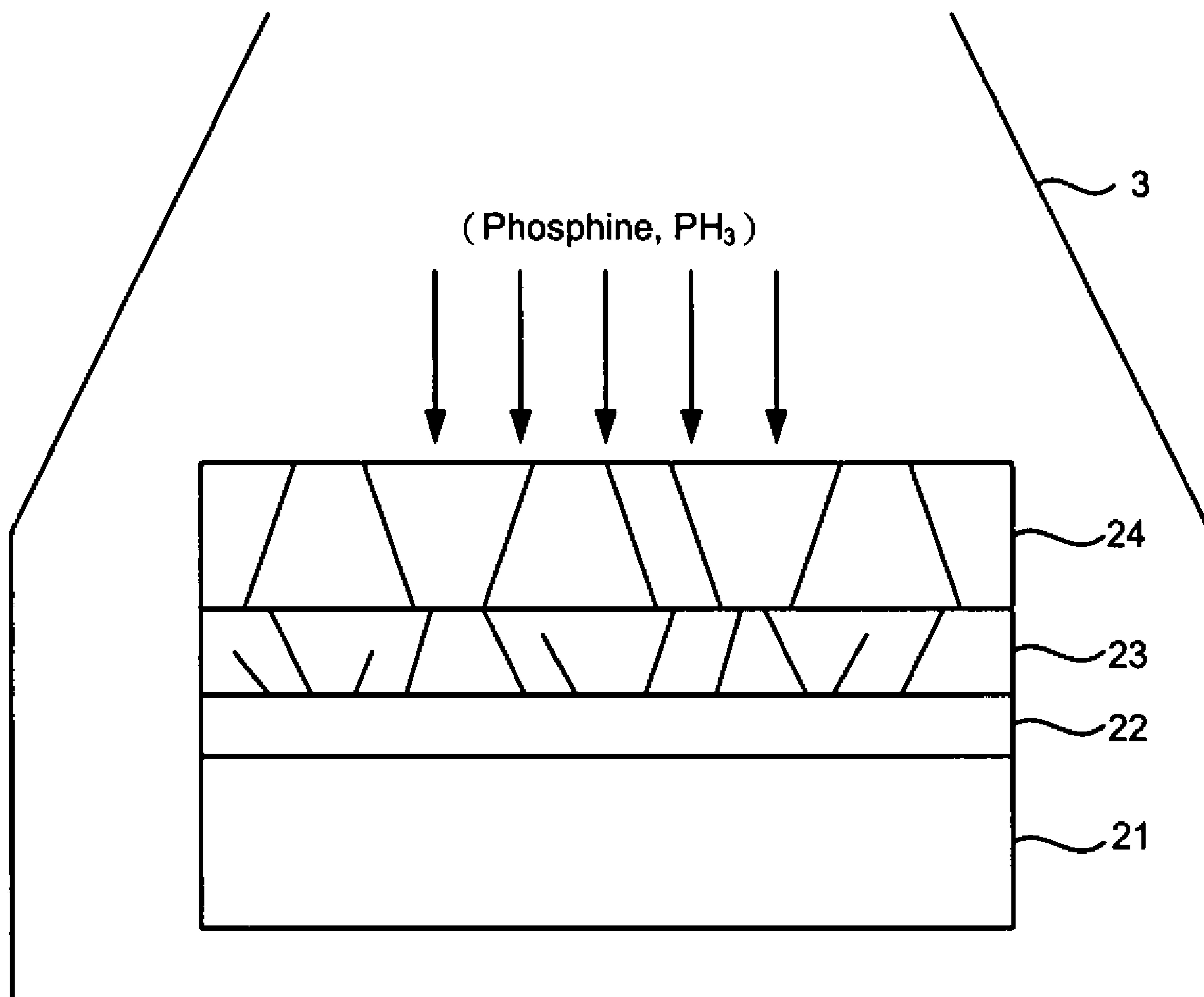


Fig. 3

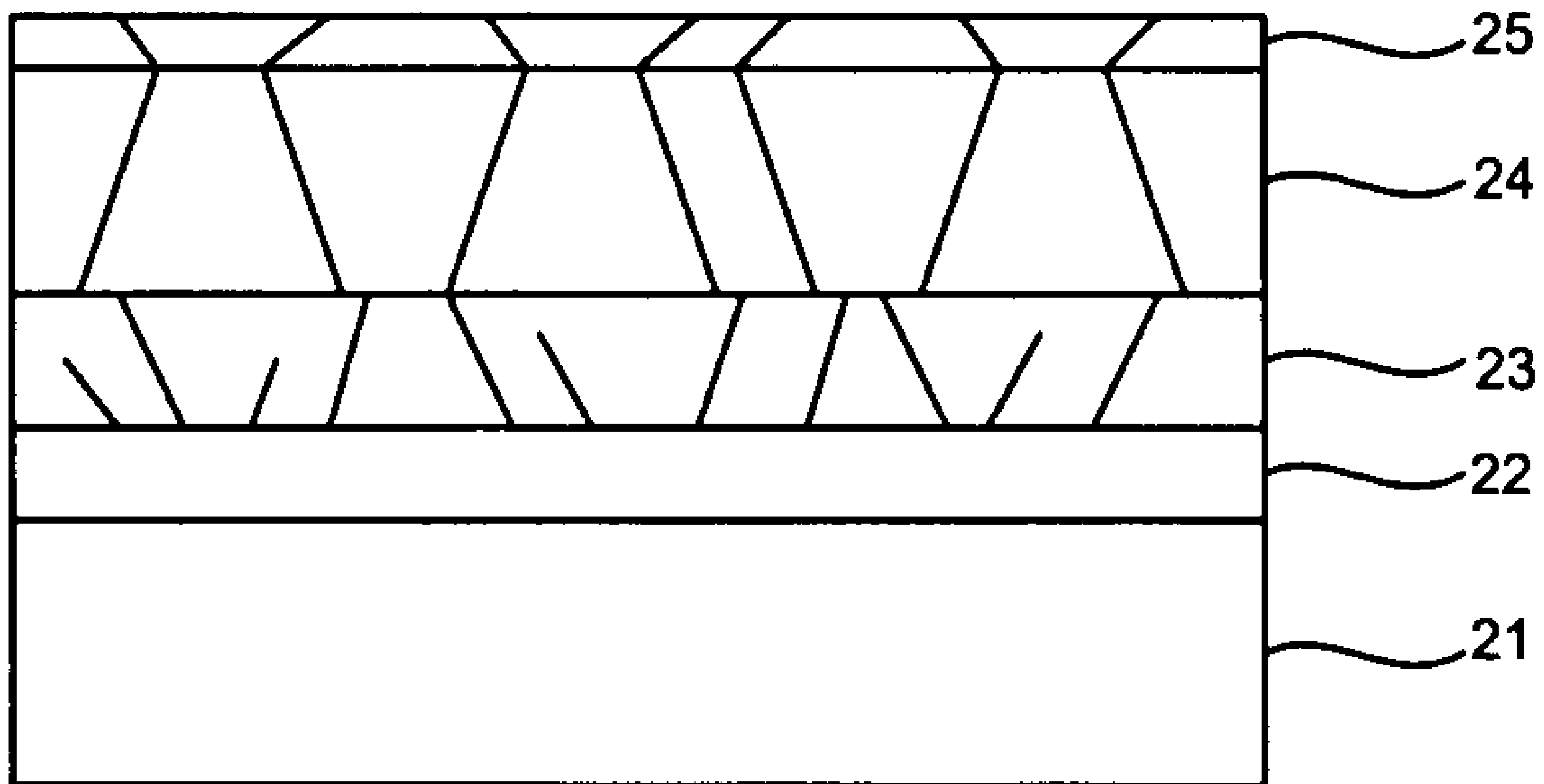


Fig. 4

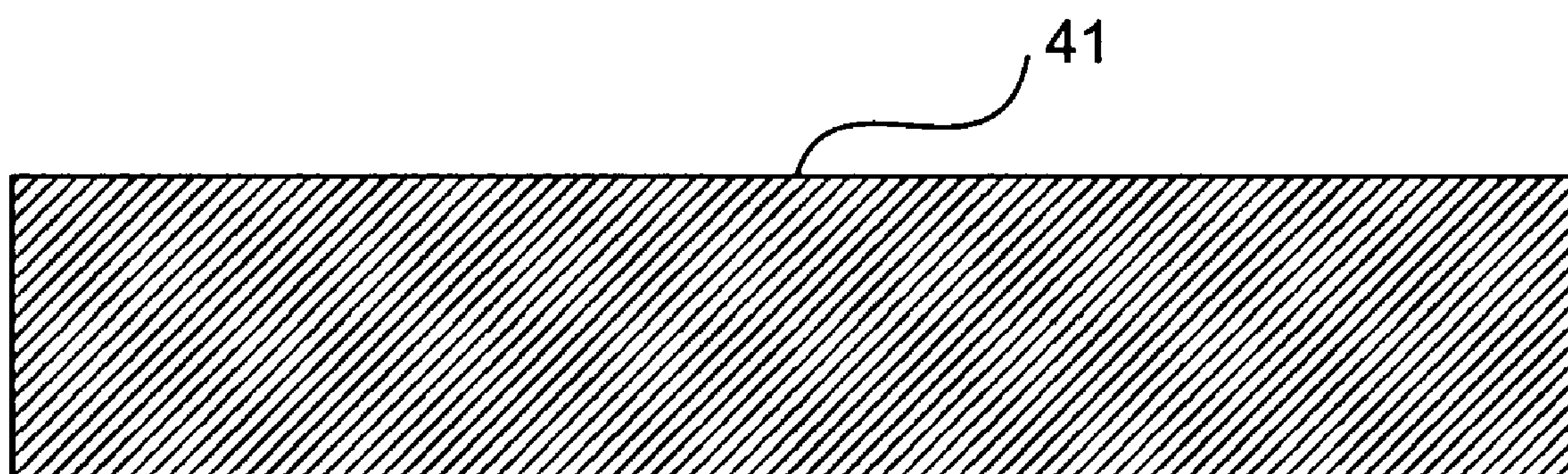


Fig. 5

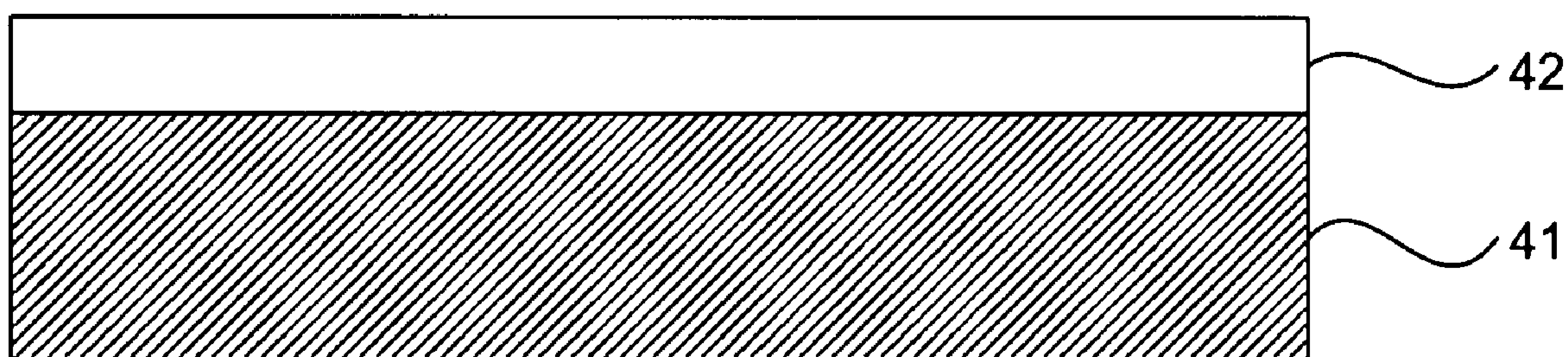
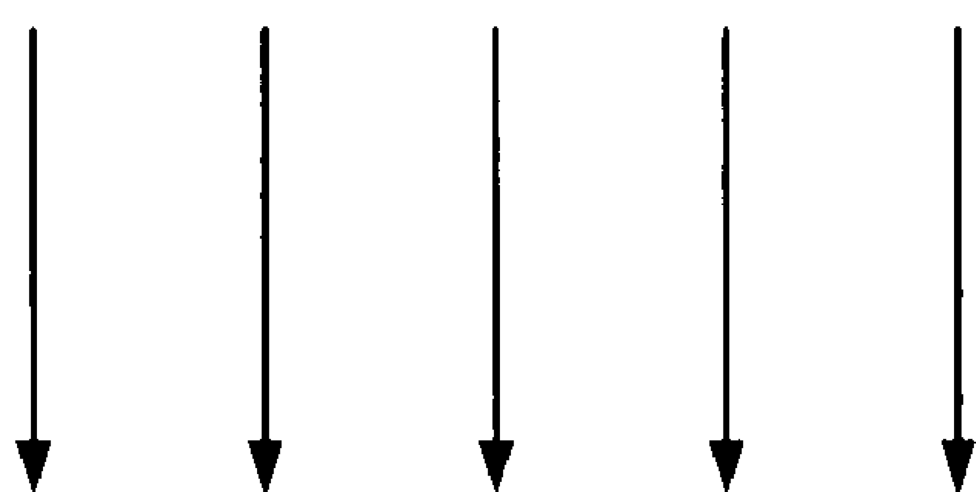


Fig. 6



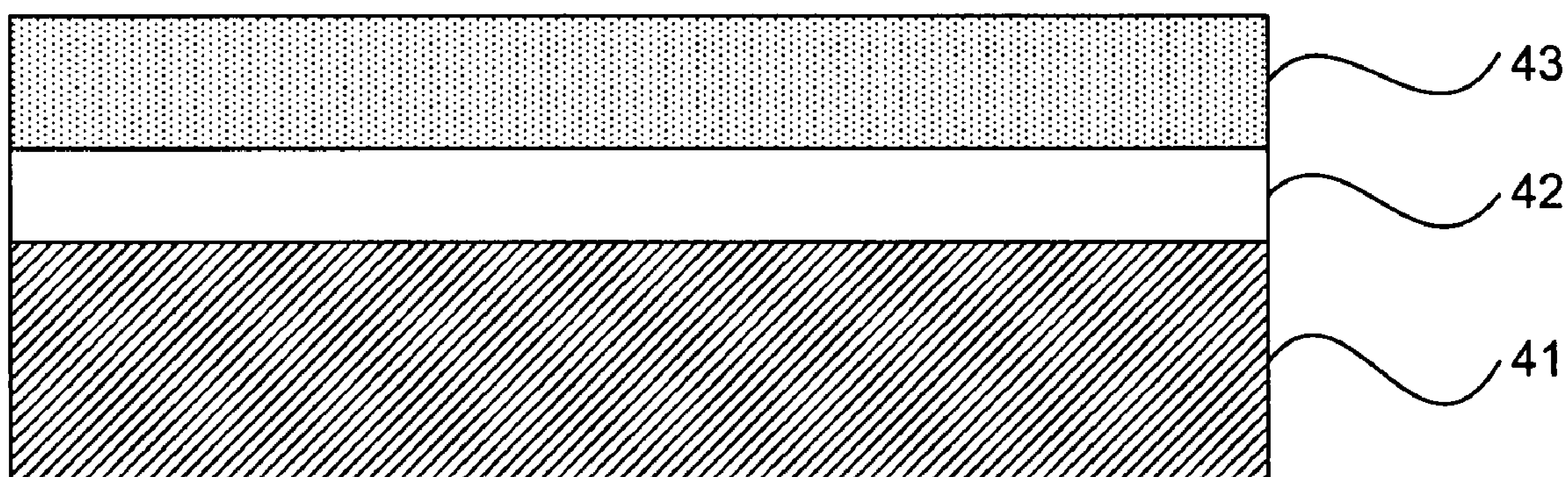


Fig. 7

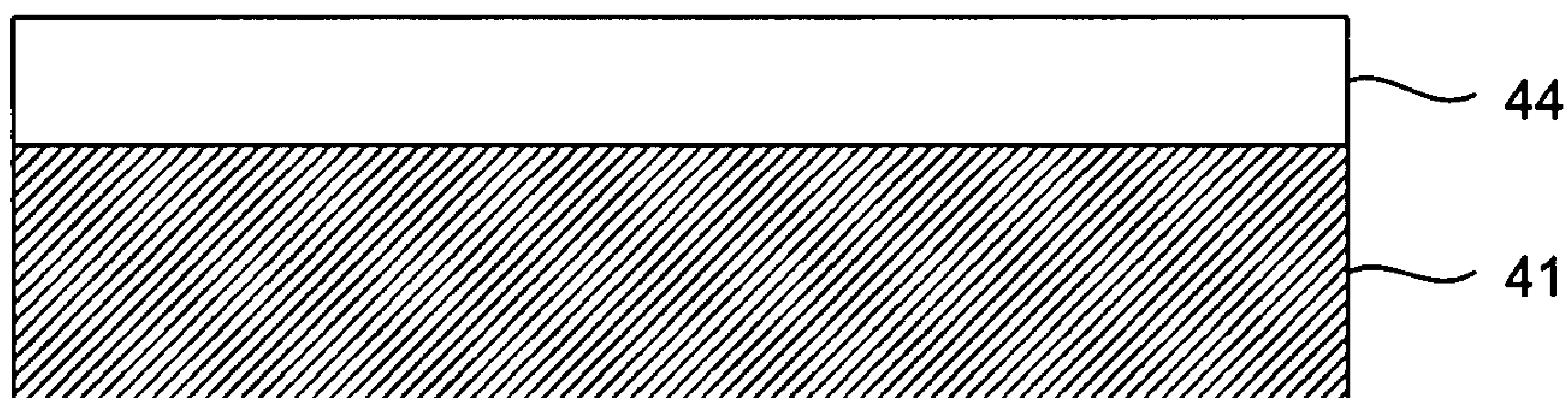


Fig. 8

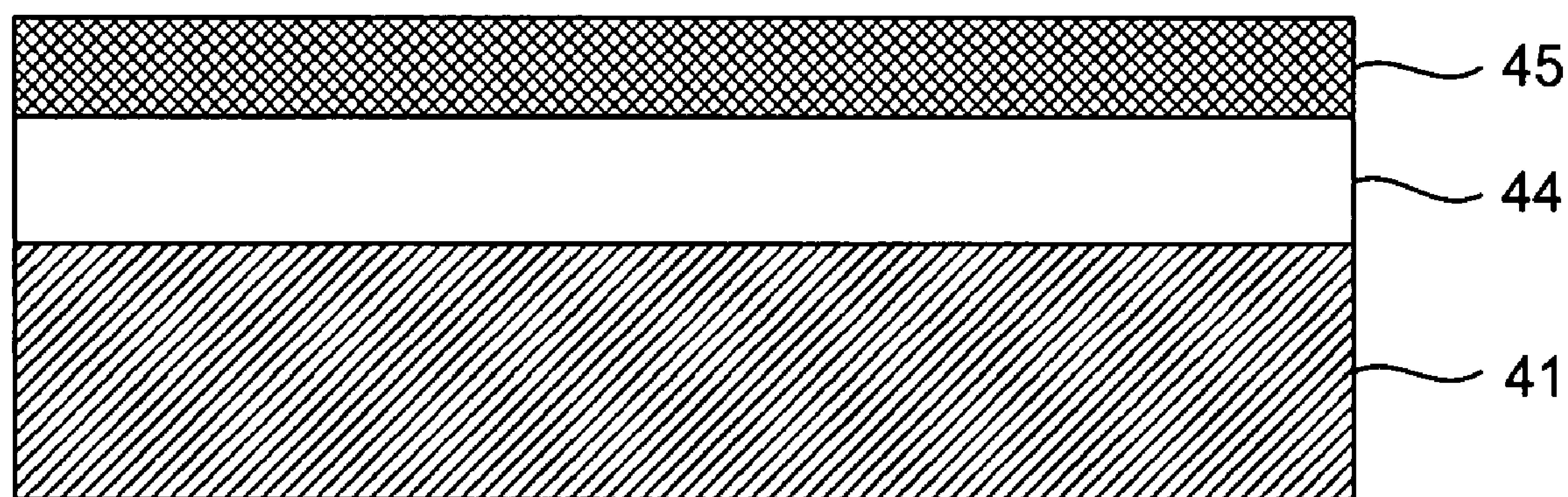


Fig. 9

METHOD FOR MAKING MULTI-CRYSTALLINE FILM OF SOLAR CELL

FIELD OF THE INVENTION

The present invention relates to a solar cell and, more particularly, to a method for making a multi-crystalline silicon film of a solar cell.

DESCRIPTION OF THE RELATED ART

Most silicon-based solar cells are made in low-temperature processes based on plasma-enhanced chemical vapor deposition ("PECVD"). An amorphous silicon or multi-crystalline silicon film is coated on a glass, aluminum, silicon, stainless steel or plastic substrate. A back contact is made of aluminum, gold, silver or transparent conductive oxide such as indium-tin oxide ("ITO") and zinc oxide.

The primary advantage of the low-temperature processes is the wide variety of materials that can be used to make the substrates. However, they suffer drawbacks such as defective silicon films, low photoelectrical conversion efficiencies and low light-soaking stability.

In the PECVD, while coating the microcrystalline silicon film, a silicon material is highly diluted in hydrogen. For example, $[H_2]/[SiH_4]>15$. That is, the concentration or flow rate of H_2 is more than 15 times as high as that of SiH_4. The problems with the PECVD are a low growth rate of the film, a long process and a high cost.

Regarding the making of the poly-silicon solar cells, there are various techniques such as solid phase crystallization ("SPC") and aluminum-induced crystallization ("AIC"). The SPC is based on the PECVD. An amorphous silicon film is deposited, intensively heated and annealed at a high temperature. Thus, a poly-silicon film with a grain size of 1 to 2 micrometers is made.

In the AIC as shown in FIGS. **5** through **9**, an aluminum film **32** is coated on a substrate **31**. An amorphous silicon film **33** is coated on the aluminum film **32** based on the PECVD and annealed at a temperature of about 575 degrees Celsius for a long time to form a seeding layer **34**. Then, it is subjected to an epitaxial process such as the PECVD or an electron cyclotron resonance chemical deposition ("ECR-CVD") to make a poly-silicon film **35**. The AIC however involves many steps and takes a long time. The resultant grain size is about 0.1 to 10 micrometers.

As discussed above, regarding the conventional methods for making poly-silicon film solar cells in the low-temperature processes based on the PECVD, there are many defects in the silicon films, the photoelectrical conversion efficiencies are low, the light soaking stabilities low, the growth rates of the films low, the processes long, and the costs high. Concerning the method for making poly-silicon film solar cells based on the AIC, the processes are long for including many steps and therefore expensive.

The present invention is therefore intended to obviate or at least alleviate the problems encountered in prior art.

SUMMARY OF THE INVENTION

It is an objective of the present invention is to provide an efficient method for making a multi-crystalline silicon film of a solar cell.

It is another objective of the present invention to provide a method for providing a quality multi-crystalline silicon film of a solar cell.

It is another objective of the present invention to provide a method for making a multi-crystalline silicon film that can be used to make a solar cell that exhibits a high photoelectrical conversion efficiency and stability of the soaking of light.

To achieve the fore-going objectives, the method includes the step of providing a ceramic substrate, the step of providing a titanium-based film on the ceramic substrate, the step of providing a p^+-type back surface field layer on the titanium-based film, the step of providing a p^--type light-soaking layer on the p^+-type back surface field layer and the step of conducting n^+-type diffusive deposition of phosphine on the p^--type light-soaking layer based on atmospheric pressure chemical vapor deposition, thus forming an n^+-type emitter on the p^--type light-soaking layer.

Other objectives, advantages and features of the present invention will become apparent from the following description referring to the attached drawings.

BRIEF DESCRIPTIONS OF THE DRAWINGS

The present invention will be described via the detailed illustration of the preferred embodiment referring to the drawings.

FIG. **1** is a flowchart of a method for making a multi-crystalline silicon film of a solar cell according to the preferred embodiment of the present invention.

FIG. **2** is a side view of a ceramic substrate, a titanium-based film coated on the ceramic substrate, a p^+-type back surface field layer coated on the titanium-based film and a p^--type light-soaking layer coated on the p^+-type back surface field layer in the method shown in FIG. **1**.

FIG. **3** is a side view of an atmospheric pressure chemical vapor deposition device for diffusively depositing phosphine on the p^--type light-soaking layer shown in FIG. **2**.

FIG. **4** is a side view of an n^+-type emitter coated on the p^--type light-soaking layer shown in FIG. **3**.

FIG. **5** is a side view of a substrate used in a conventional method for making a multi-crystalline silicon film.

FIG. **6** is a side view of an aluminum film coated on the substrate shown in FIG. **5**.

FIG. **7** is a side view of an amorphous silicon film coated on the aluminum film shown in FIG. **6**.

FIG. **8** is a side view of the substrate coated with a seed layer converted from the amorphous silicon film and the aluminum film shown in FIG. **7**.

FIG. **9** is a side view of a multi-crystalline silicon film coated on the seed layer shown in FIG. **6**.

DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, shown is a method for making a multi-crystalline silicon film of a solar cell according to the preferred embodiment of the present invention.

Referring to FIGS. **1** and **2**, at **11**, a ceramic substrate **21** is provided. The ceramic substrate **21** is made of aluminum oxide. The thickness of the substrate **21** is about 0.1 to 1.0 mm.

A titanium-based film **22** is coated on the ceramic substrate **21**. The thickness of the titanium-based film **22** is about 1000 to 5000 angstroms. The titanium-based film **22** is used both as a back contact and a seed layer. The titanium-based film **22** is made of $TiSi_2$, TiN, TiC, TiB_2 or TiC_xN_y.

The epitaxial growth of a p^+-type back surface field ("BSF") layer **23** is conducted on the titanium-based film **22**. The thickness of the p^+-type BSF layer **23** is no larger than 1 micrometer.

The epitaxial growth of a p^--type light-soaking layer **24** is conducted on the p^+-type BSF layer **23**. The thickness of the p^--type light-soaking layer **24** is about 15 micrometers. The size of silicon crystals **241** at grain boundaries **242** in the p^--type light-soaking layer **24** is larger than 10 micrometers.

Referring to FIGS. **1** and **3**, at **12**, in an atmospheric pressure chemical vapor deposition ("APCVD") device **3**, at about 800 to 1000 degrees Celsius, phosphine is diffusively deposited on the p^--type light-soaking layer **24**. Thus, the n^+-type diffusive deposition of the phosphorous atoms of the phosphine is conducted on the p^--type light-soaking layer **24**.

Referring to FIGS. **1** and **4**, at **13**, an n^+-type emitter **25** is coated on the p^--type light-soaking layer **24**. The thickness of the n^+-type emitter **25** is smaller than 1000 angstroms. The concentration of the phosphorous atoms in the n^+-type emitter **25** is about 10^{18} to 10^{19}#/mm^3.

As discussed above, the atmospheric pressure chemical vapor deposition process is conducted at a high temperature. The ceramic substrate **21** is made of aluminum oxide. The titanium-based film **22** is used both as the back contact and the seed layer. The epitaxial growth of the P^+-type BSF layer **23** and the p^--type light-soaking layer **24** is directly conducted on the titanium-based film **22**. The n^+-type diffusive deposition is conducted on the p^--type light-soaking layer **24**. Thus, the n^+-type emitter **25** thinner than 1000 angstroms is formed. Moreover, as multi-crystalline silicon exhibits high electron-hole mobility, large electron-hole diffusion length and long electron-hole recombination, the solar cell made according to the present invention exhibits a high epitaxial growth rate, excellent crystal quality, a high photoelectrical conversion efficiency and stable light-soaking. In addition, the cost of equipment is low, and the process simple.

The present invention has been described via the detailed illustration of the preferred embodiment. Those skilled in the art can derive variations from the preferred embodiment without departing from the scope of the present invention. Therefore, the preferred embodiment shall not limit the scope of the present invention defined in the claims.

What is claimed is:

1. A method for making a multi-crystalline silicon film of a solar cell, the method comprising the steps of:

providing a ceramic substrate;

providing a titanium-based film on the ceramic substrate;

providing a p+-type back surface field layer on the titanium-based film;

providing a p−-type light-soaking layer on the p+-type back surface field layer; and

conducting n+-type diffusive deposition of phosphine on the p−-type light-soaking layer based on atmospheric pressure chemical vapor deposition, thus forming an n+-type emitter on the p−-type light-soaking layer.

2. The method according to claim **1**, wherein the titanium-based film is made of a material selected from a group consisting of $TiSi_2$, TiN, TiC, TiB_2 and TiC_xN_y.

3. The method according to claim **1**, wherein the thickness of the titanium-based film is about 1000 to 5000 angstroms.

4. The method according to claim **1**, wherein the titanium-based film is used both as a back contact and a seed layer.

5. The method according to claim **1**, wherein the thickness of the ceramic substrate is about 0.1 to 1.0 mm.

6. The method according to claim **1**, wherein the thickness of the p^+-type back surface field layer is no larger than 1 micrometer.

7. The method according to claim **1**, wherein the thickness of the p^--type light-soaking layer is about 1 to 15 micrometers, and the grain size of the p^--type light-soaking layer is larger than 10 micrometers.

8. The method according to claim **1**, wherein the n^+-type diffusive deposition is conducted at 800 to 1000 degrees Celsius.

9. The method according to claim **1**, wherein the thickness of the n^+-type emitter is smaller than 1000 angstroms.

10. The method according to claim **1**, wherein the concentration of the phosphorous atoms in the n^+-type emitter is about 10^{18} to 10^{19}#/mm^3.

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